CAUSES, CONSEQUENCES AND CONTROL OF EXCESSIVE AQUATIC PLANT GROWTHS IN LAKE ST. FRANCIS

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CAUSES, CONSEQUENCES AND CONTROL

OF EXCESSIVE AQUATIC PLANT GROWTHS

IN LAKE ST, FRANCIS

by

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SUMMARY

A study was undertaken in 1973 to document the increasing proliferation of aquatic vegetation in Lake St. Francis and to evaluate the potential causes, resultant adverse effects and the technological and ecological implications of selected weed control measures.

Based on information obtained from long-time residents, previous field observations and various technical reports, it is evident that ecological changes of major proportions have occurred in the Northern section of Lake St. Francis since the construction of the St. Lawrence Seaway. These changes are primarily manifested in the shifts in plant specie dominance and in the increase in the extent and abundance of weed growths. The present extent of plant growth is clearly documented in a series of maps prepared from data obtained from an aerial photographic survey. Measurements of biomass show considerable variation in plant densities with values ranging between 78.3 and 1635.3 grams per m^2 dry weight, however, the values obtained are largely comparable to those reported for other highly productive environments. Communities of invertebrate organisms which inhabit lake sediments have also been altered both in terms of their composition and abundance. This has undoubtedly been compensated for by an increase in the diversity and abundance of aquatic organisms which utilize the aquatic plants as a substrate. Similarly, changes in the fish populations, although poorly documented have materialized. Available data suggest an increase in the productivity of some fish species which occupy weedy habitats (i.e. yellow perch) and a decline in other fish species.

The accumulation of finer, predominantly organic sediments over extensive areas of shallow water has been identified as the primary cause of the changes which have occurred in Lake St. Francis. This sedimentation is a direct result of the decrease in current velocity brought about by major alterations in flow patterns following dredging of the navigation channel. Other changes in the hydrological features of the river have been assessed as lesser but nevertheless contributary factors.

The tremendous proliferation of weed growth in Lake St. Francis has adversly affected a variety of recreational uses, shoreline property values, tourist trade and to some degree the commercial fishery. The magnitude of the impact on lake usage and the local economy has not been fully assessed.

The major ecological changes which have occurred in Lake St. Francis are likely of an irreversible nature. The application of control measures, including weed harvesting and dredging of secondary channels, to selected problem areas would greatly enhance recreational usage without significant ecological risk.

INTRODUCTION

This report deals with the relatively recent occurrence and effects of excessive production of aquatic vegetation in Lake St. Francis. Changing conditions with respect to the type, distribution and abundance of rooted submergent and emergent aquatic vegetation were apparent to local residents familiar with conditions on the lake during the early part of the 1960's. Later in the course of water quality and related biological studies of Lake St. Francis carried out in 1967, Ministry biologists became aware of these changes and resulting water-use problems through information obtained by personal contacts with commercial fishermen, anglers, guides, marina operators, cottagers and permanent residents on the lake and through preliminary field observations of the species composition, extent and abundance of weed growth. A general description of these observations was included in a 1968 report entitled *"Preliminary Biological Surveys of the St. Lawrence River, 1966-1967"*. Since that time, further observations made in the course of more recent water quality surveys have indicated a continuation of this trend and an increasing and more widespread concern on the part of local residents over the deteriorating aesthetic conditions, decreased use potential of the lake and the resultant local economic effects. Representations have been made to various levels of government and jurisdictions by individuals, conservation groups and other associations stressing the seriousness of the problem and the need for control measures. Although a broader awareness of the magnitude of the problem has resulted little has been accomplished with regard to the implementation of a control programme.

Presently there are several obstacles to large-scale weed control efforts including a lack of definition of the jurisdictional or general responsibility for the development, implementation and financing of such programmes; the relatively high costs involved without a clear definition of the economic or other benefits to be derived; technological difficulties; and in view of the lack of experience and/or the necessary research, concern over possible adverse ecological side-effects. A recognition of the need and desirability for large-scale weed control measures to improve the over-all usefulness of lakes that are characterized by extensive weed infestations led to a co-operative study by the Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources to evaluate the efficacy of weed harvesting techniques and ecological implications in Chemung Lake, Peterborough County. While the study is necessarily of a long-term nature

and final conclusions have not been made, preliminary results, at least, are encouraging and are felt to be applicable to Lake St. Francis.

With the considerable information that is now available this report has been prepared to provide an assessment and documentation of the problem and to deal with the technological and ecological aspects of possible control measures.

DESCRIPTION OF THE PROBLEM

The following sections provide a general description of physical, chemical, biological and water use characteristics of Lake St. Francis and the changes which have occurred in these characteristics as background to a more detailed presentation of the findings of the 1973 study and discussion of causes and possible solutions to the problem. For reference purposes, the reader should refer to chart 1413, (Cornwall to Lancaster Bar) published by the Canadian Hydrographic Service and also to charts 1412 and 1414, (Cat Island to Beauharnois Canal).

Physical Characteristics

The emphasis of this report is on the approximately 15 mile long section of the river between Cornwall and South Lancaster comprising the upper portion of Lake St. Francis which extends for approximately 32 miles from Cornwall downstream to Valleyfield, Quebec.

The long-term average discharge of the St. Lawrence River at Cornwall is 240,000 cubic feet per second (cfs). The following table describes discharge characteristics for the period 1959-1971 based on records supplied by the International St. Lawrence River Board of Control.

Mean cfs (X1000)

	Annual	Monthly		Daily	
		Max.	Min.	Max.	Min.
1959	223	263	178	265	164
1960	239	290	209	307	195
1961	231	279	204	283	195
1962	211	231	191	237	179
1963	206	217	188	237	173
1964	201	212	179	220	165
1965	192	206	176	209	159
1966	220	234	203	245	195
1967	221	233	212	240	176
1968	252	270	237	280	210
1969	266	295	235	299	210
1970	250	265	228	280	200
1971	258	285	235	287	220

Maximum mean monthly discharge for most years occurs in June. Until 1971 the Moses-Saunders Generating Station was operated on the basis of "peaking power" but since has been operated at full continuous capacity with a permitted discharge variation of ± 30,000 cfs of the weekly mean discharge.

Water levels of Lake St. Francis are affected by discharges through the Moses-Saunders dam and the Long Sault control dam but are controlled principally by the control dam and the Hydro Quebec power dam at Beauharnois, Quebec. Data provided by the Canadian Hydrographic Service as measured at Summerstown, Ontario for the period 1964-1970 show that mean monthly levels fluctuated narrowly between 153.50 feet and 152.07 feet above mean sea level for the period. Total fluctuation within each year did not exceed 2 to 3 feet.

At Cornwall, approximately two thirds and one-third of the total discharge passes through the international channel and the Cornwall channel, respectively. Through upper Lake St. Francis flows diverge into several major channels with many smaller channels diverging from and re-entering the major channels. As the lake widens from 2 miles to approximately 4.5 miles, flow rates which are variable depending on channel dimensions, generally decrease. Channels vary in width from several hundred feet to as much as 1500 feet and for the most part depths in the major channels are greater than 30 feet with maximum depths of 70 to 80 feet. Depths in secondary channels vary from 20 to 30 feet. Between these channels and occupying most of the lake are extensive areas of shallow water with relatively uniform depths varying from 2 to 4 feet and up to 12 feet in deeper depressions. In the development of the St. Lawrence Seaway, extensive alterations were made in the most northerly major channel to accommodate ship traffic. These consisted of straightening and deepening of shallower sections to a uniform depth of 28.5 feet.

Sediment characteristics throughout the lake are extremely variable being determined largely by flow patterns. In deeper channels sediments are coarse-textured sand, gravel and shell detritus with varying amounts of exposed hard-pan clay. Deeper sediments of shallow areas are also coarse-textured but are overlain by varying and undetermined depths of clay, silt and organic matter of more recent origin.

Water Quality

Water quality data for the St. Lawrence River are available only for the years post-dating Seaway development. These have been derived from various surveys which were undertaken to determine the status of municipal pollution control (O.W.R.C. 1959, 1960A, 1960B, 1964A, 1964B, 1965 and 1966), an extensive survey of water quality in Ontario waters from Kingston to the Quebec boundary (O.W.R.C., 1965), water quality monitoring surveys undertaken by the Federal Department of Health and Welfare from 1965-1967 inclusive (I.J.C., 1969) and from water quality and biological surveys in 1966-67 (Owen and Veal, 1968) and more recently in 1970 (unpublished). Data for Lake St. Francis are available only from the surveys of 1965, 1966, 1967 and 1970.

A summary of these data shows that, in general, favourable water quality conditions prevail throughout the length of the river and largely reflect the quality of water of the eastern basin of Lake Ontario. Major point source discharges of industrial and municipal wastes and tributaries draining productive agricultural land result in minor adverse effects on water quality in areas of initial dilution but do not alter the overall quality of the river.

At Cornwall, prior to 1970, an industrial waste volume of approximately 55 MGD and effluents of several smaller industries and domestic wastes from a population of approximately 44,000 were discharged untreated to the river at several locations. Treatment of domestic wastes and a waste volume of 1.2 MGD from smaller industries was effected in 1970 with the completion of a sewer system and a 8.25 MGD capacity primary sewage treatment plant with an extended outfall into the main stream of the Cornwall Channel west of Pilon Island. Also, since 1970, a reduction of at least 70% has been achieved in suspended solids loadings from the Cornwall mill of Domtar Fine Papers Limited.

Results of comparative surveys of 1967 and 1970 have shown a significant improvement in most water quality parameters within the Cornwall channel and adjacent to the north shore downstream past Glen Walter. In both surveys adverse effects, based on an examination of routine water quality parameters, were not detected further downstream in Lake St. Francis where results for both surveys were comparable. Variations in levels of nitrogen, phosphorus and water clarity, have been of a small magnitude throughout the river and it is not likely that there was a significant, sustained trend

towards change in these parameters prior to 1960. Concentrations of total nitrogen and total phosphorus have averaged 0.5 mg/l and 0.03 mg/l, respectively. Secchi disc visibility, as a measure of water clarity, has averaged 10 feet upstream of Lake St. Francis and has ranged between 14 and 18 feet in Lake St. Francis,with the exception of the main navigational channel where generally more turbid conditions have prevailed presumably due to disturbance of sediments by passage of ships through sections of minimum depth and perhaps other factors.

Biological Characteristics

Records pertaining to biological and ecological conditions in Lake St. Francis, particularly prior to Seaway development, are scant. What little is known is available from records of the Ontario Ministry of Natural Resources pertaining to commercial fisheries harvest, creel census and perhaps trapping and waterfowl surveys and from biological sampling undertaken in conjunction with the water quality surveys of 1966, 1967 and 1970. The study of aquatic vegetation completed in 1973 has provided more detailed knowledge of weed species, estimates of biomass and a mapping of the distribution of weed beds. Also, Lalonde (1973) has described the changes in weed growth that have occurred based on his personal knowledge of the river and observation by others.

From general recollections of conditions prior to and following Seaway development and from observations made in recent studies, it is possible to gain an appreciation of the nature and magnitude of environmental changes that have occurred. Before the Seaway extensive areas of shoal flats bordering the primary and secondary river channels in the Ontario portion of upper Lake St. Francis were apparently covered by well-sorted, coarse-textured sediments consisting of sand and gravel with areas of hard-pan clay. Aquatic vegetation consisted of stands of bulrush, (*Scirpus sp)* on sand in shallower areas and sago pondweed (*Potamogeton pectinatus)*and to a lesser extent wild celery *(Vallisneria americana)* at various depths. During the early 1960's a variety of rooted submergent species became established concurrent with a decrease in flow rates and accumulation of finer sediments. New species associations and the present extent of weed beds were probably stabilized by as early as 1966 judging by observations made in 1966 and 1973. Weed density, however, and perhaps rate of growth has apparently increased steadily to the present time to the point where in virtually all areas, with the exception of deeper channels, dense mats are formed on the surface

of the water throughout the latter stages of the growing season. Finer sediments comprised of silt, clay and organic matter mixed with fragmented remains of vegetation have accumulated in varying amounts.

The extent to which other biological features have been altered through changes in weed growth and other physical factors is not fully clear. While certain features have changes, the significance of other trends and the importance of various other factors have not been well established. Whereas bottom organisms were once abundant and comprised chiefly of snails, clams *(Sphaeriidae)* and larvae of aquatic insects, communities are now comprised primarily of burrowing forms, and their abundance has been much reduced. This loss has probably been largely compensated for by the development of a diverse and abundant fauna utilizing aquatic plants as a substrate. This change, along with a shift in plant species to those of lesser value as a food source may account for the reported decrease in the numbers of diving ducks which were once plentiful in this portion of the lake during spring and fall migration and may also account for shifts in the relative abundance of some fish species. According to Baldwin (1974, pers comm), yellow perch which have always been an important part of the sport fishery have apparently further increased in abundance, as have sunfish and perhaps other species that occupy weedy habitats. Also, northern pike have increased in importance in the sport fishery in the past three years. The status of yellow pickerel at the present time is uncertain although there are some indications of a decline reportedly related to a partial loss of spawning shoals after development of the Seaway and possibly to other factors. Bottom feeders such as channel catfish, sturgeon and perhaps bullheads have apparently decreased as well.

Contrary to general opinion, our observations have not indicated gross ecological changes in other portions of the lake, specifically in Quebec waters of the southern portion of the upper part of the lake, where flows are carried by several, well-defined channels and neither these channels nor their flow rates appear to have been significantly altered since completion of the Seaway. Conditions of relatively stagnant water exist on the shallow flats between these channels and extensive cattail marshes have developed. The advanced stage of plant succession in these areas is indicative of relatively stable conditions over a long period of time and is also indicative of the direction in which plant succession is probably now proceeding in the affected northern portions of the lake.

Water Uses

The St. Lawrence River and Lake St. Francis support a multiplicity of industrial and recreational water uses having significant importance to national, provincial and local economies. These include generation of hydro-electric power, commercial shipping, domestic and industrial water supplies, waste water assimilation, commercial fisheries and a variety of recreational pursuits including cottaging, pleasure boating, swimming, angling, waterfowl hunting and sight-seeing.

The established priority and importance of commercial shipping and power production has been well recognized for many years. Completion of the Seaway and the Moses-Saunders dam at Cornwall in 1958, providing deep water navigation between Montreal and Lake Ontario and an additional, combined generating capacity of 1.8 million Kilowatts, has added further to this importance. A description of these works and commercial shipping statistics are available in several publications and have been summarized by the St. Lawrence Seaway Authority (1969). Similarly, the present importance and future potential for water supplies and waste assimilation uses are well recognized and need no further elaboration. On the other hand, commercial fisheries and recreational activities on Lake St. Francis have not been as well documented although the extent of these uses and their importance to the local economy is well known locally.

Provincial government publications have provided current statistics on tourist traffic, facilities and expenditures (Ontario Ministry of Tourism and Information, 1972 and 1973; Ontario Ministry of Natural Resources, 1973). In addition, commercial fisheries records have been maintained by the Ministry of Natural Resources.

Since 1966, two commercial fishermen have held licenses on Lake St. Francis and prior to that a third fisherman accounted for much of the catch. Total catch decreased from 124,768 pounds in 1964 to 38,846 pounds in 1969. In 1970 commercial fishing was banned due to excessive levels of mercury in fish flesh. Bullheads and catfish were removed from the restricted list in 1971 but this has resulted in only a minimal operation, (Ramsbottom, 1974). While excessive weed growths have undoubtedly interfered with the efficiency of conventional fishing gear, the decline in the commercial fish harvest can more likely be attributed to economic,cultural and pollutional factors.

Although sufficient statistics are not available to clearly document the extent and importance of recreational uses, an appreciation can be gained through a general description of activities and related facilities. The existence of major east-west transportation routes adjacent to Lake St. Francis and the international bridge at Cornwall exposes the area to a high level of tourist traffic. A major portion of the population and development of Charlottenburgh Township lies along the north shore of the lake. From Ontario Hydro records for seasonal residence contracts, it is estimated that there are approximately 900 cottages along this shoreline. An unknown but undoubtedly far greater number of permanent residences exist, including the populations of Glen Walter, Summerstown and South Lancaster. Commercial facilities include several motels and hotels, five marinas and two provincial parks.

Excessive aquatic weed growths have reportedly had significant adverse effects on recreational activities and tourist trade. While these effects have not been well documented or quantified they are nevertheless real (Lalonde; 1973), the only question being the extent to which the local economy has been affected. The major effects are summarized under the following use categories.

Swimming

Along most shorelines, swimming during the months of July and August is seriously impaired and in places virtually impossible without some form of local weed control being applied. Many sections of this shoreline have been described as being previously sand beaches free of weed growth.

Pleasure Boating

Access to confined waters and across extensive areas of shallow water has become extremely difficult. Unobstructed boating is possible only in major secondary channels where boat traffic has kept weeds cropped below the surface.

Angling

There are conflicting reports as to recent changes in the quality of angling and factual evidence is generally lacking. Stocks of sport fish have undoubtedly changed in response to changes in habitat. It is felt, however, that increased weed growth has contributed favourably

to the overall sport fishery particularly with respect to increased productivity of yellow perch and northern pike (Ramsbottom, 1974). However, boating access is restricted and the weeds do create a physical impediment to angling.

Aesthetic Conditions

Aesthetic qualities have grossly deteriorated through excess weed production. Weeds reaching the surface in mid-summer eliminate areas of open water and give an appearance of marshland to an extensive area of the lake. Floating weeds accumulate in quantity along shorelines where they create unsightly conditions and decompose causing odour problems. The incidence of dead fish, caused by passage through turbines, has increased. These fish are caught up in weed beds and further add to the unsightly and malodorous conditions.

FIELD SURVEY OF LAKE ST. FRANCIS

To more accurately document the extent and abundance of plant growths in Lake St. Francis, a field survey was carried out on August 27, 28 and 29 of 1973, followed by aerial overflights of the north shore in early September.

Methods

Due to time limitations, the survey was largely comprised of a visual assessment of the problem areas. However, to provide some information on the biomass and specie composition, vegetation was collected from 1/4 m^2 quadrats placed along visual transects which were established at the following locations:

Transect 1: Between Faulkners Pt. and navigation channel (82 F).

Transect 2: From Fraser Point towards navigation channel (96 F).

Transect 3: From Jack's Marina towards navigation channel (115 F).

Transect 4: From east end of Motel near McGibbons Point towards channel (123 F).

Transect 5: From roadway near Flaningan's Point towards channel (133 F).

Transect 6: From west end of Pilon Island towards channel (140 F).

Plants growing within the quadrats were collected, sorted, identified, oven dried and weighed to establish the biomass in grams per m^2. In addition, information on water depth, water clarity (as measured by Secchi disc) and substrate type was recorded at each sampling site. Water milfoil plants were also collected from various sites above and below the Moses-Saunders Dam and analyzed for tissue concentrations of nitrogen and phosphorus.

Aerial photography was used to supplement field data and to provide information on plant distribution. Overflights of the north shore of the

St. Lawrence River between Morrisburg and Lancaster Bar were completed in early September 1973, utilizing conventional colour film #2445 at an altitude of 5000 ft. (1524m). Imagery obtained from these overflights was used to develop detailed maps of the distribution of aquatic vegetation throughout the area.

Results and Discussion

The distribution of aquatic vegetation along the north shore, between Morrisburg and Lancaster Bar has been illustrated in figures 1,2 and 3. Visual examination of the Lake St. Francis area generally revealed prolific plant growths which formed dense, impenetrable beds and encroached on many boating routes which provide access to the main navigation channels. Water milfoil, *Myriophyllum exalbescens**, was the most prominent plant in deeper areas, usually forming dense stands which reached the surface and created stagnant conditions within the weed bed. Sago pondweed, *Potamogeton pectinatus*, occurred in many of the channels, growing in long stands, often exceeding 10 feet, which were usually flattened against the bottom by the currents. Plant communities in the bays and nearshore areas were more diverse and usually did not reach the water surface. Tapegrass, *Vallisneria americana* was perhaps the most prominent plant in these areas, particularly on sandy substrates. A list of the plant species identified during the survey has been included in Table 1. Brief sketches of these plants have been provided in Figures 4 and 5 to aid in the recognition and identification of the vegetation.

Information obtained from sampling along five established transect lines has been summarized in Table 2. Water clarity, as measured by secchi disc was generally good ranging between 2.5 and 4.6 meters (8 to 15 feet). By comparison, in August, 1973, values between 1.4 and 2.2m were recorded for Chemung Lake where light penetration is a major factor in restricting the growth of rooted plants in deeper waters. Substrates were predominantly comprised of a grey coloured silt although, sand, black muck and clay were found in some areas.

The biomass of the plants varied considerably with water depth, substrate type and sampling site from a minimum of 78.3 grams dry weight per square meter (0.35 tons/acre) near McGibbons Point to an exceptionally high value of 1635.3 grams (7.3 tons/acre) near Pilon Island. Similar high values have been recorded in the literature, i.e. 1,146 grams/m ash-free dry weight in Lake Wingra (Nichols, 1971) although according to Boyd (1971) submersed and floating leaved aquatic plants usually have standing crops of less than

500 grams dry weight per square meter. Biomass values obtained in Chemung Lake in August 1973 averaged 283.9 g/m^2 (1.27 tons/acre) dry weight with a maximum value of 934.8 g/m^2 recorded at one sampling station.

Nutrient levels in water milfoil plants collected from various sites above and below the Moses-Saunders Dam have been summarized in Table 3. Tissue concentrations ranged between 1.8 and 3.5% of the dry weight for nitrogen and 0.20 and 0.39% for phosphorus. The maximum concentrations of 3.5% N and 0.39% P obtained at Station 3, near the Cornwall sewage treatment plant outfall, were somewhat higher than the values obtained in Chemung Lake during late August, (0.98 - 2.6% N and 0.10 - 0.33%). Considerable evidence exists in the literature to indicate that the uptake of nutrients by aquatic plants is greater with increasing environmental levels of these elements. For example Fish and Will (1966) found concentrations of 2.8% N and 0.34% in plants growing in the oligotrophic Lake Okataina compared to 4.48% N and 0.75% P in the highly enriched Lake Rotorua, New Zealand. Similarly Caines (1965) reported significant increases in phosphorus concentrations in plant tissues following fertilizer additions to their environment.

Gerloff and Kromblantz (1966) considered the concentrations of an element in plant tissues as a reliable indicator of the supply of that element in the environment and used plant tissue analysis as an index of the availability of nitrogen and phosphorus in natural waters. Based on their data, the authors established critical tissue concentrations of 1.3% N and 0.13% P. Plant tissue concentrations below these critical levels would indicate that plant growth is limited by the supply of these elements. In all instances, tissue concentrations of nitrogen and phosphorus in the plants collected from the St. Lawrence river were well above these critical levels, indicating that plant growth was not limited by the supply of these nutrients.

* *Water milfoil specimens collected during the 1973 survey were identified as Myriophyllum exalbescens Fernald., however, the occurrence of Eurasian milfoil, Myriophyllum spicatum L. in the St. Lawrence River has been previously noted (S. Aiken - personal communication). Eurasian milfoil is an introduced plant specie with a high reproductive potential which has invaded many waterways throughout the U.S.A. creating severe nuisance conditions.*

Table 1: Aquatic plants of the Lake St. Francis area of the St. Lawrence River.

Scientific Name	Common Name(s)
Myriophyllum exalbescens Fernald.	water milfoil
Vallisneria americana Michx.	tapegrass, wild celery
Elodea canadensis (Michx) Planchon	elodea, Canada waterweed
Ceratophyllum demersum L.	coontail
Potamogeton pectinatus L.	sago pondweed
Potamogeton richardsonii (Benn.) Rydb.	Richardson's pondweed, clasping-leaf pondweed, bass weed
Najas flexilis (Willd.) Rostk. and Schmidt	bushy pondweed
Heteranthera dubia (Jacq.) Mac M.	water star grass
Lemna trisulca L.	star duckweed
Alisma gramineum Gmel.	narrow-leaf water plantain

Table 2: Summary of specie composition and plant biomass at five sampling sites in Lake St. Frances.

Location	Water Depth (m)	Secchi disc- (m)	Substrate type	Plant species present	Biomass expressed in grams dry weight per meter square	Equivalent tons per acres dry weight	Estimated fresh weight in tons per acre
Transect 1.							
Stn. 1.	1.5	1.5	Sand	V. americana, . demersum, E. canadensis, L. trisulca, H. dubia	178.0	0.79	7.9
Stn. 2.	2.9	2.9	Sand	M. exalbescens, V. americana, E. canadensis, C. demersum, L. trisulca, N. flexilis.	152.4	0.68	6.8
Stn. 3.	4.6	4.6	Silt	M. exalbescens, V. americana, E. canadensis, C. demersum. H. dubia, L. trisulca.	227.1	1.0	10.0
Stn. 4.	2.1	2.1	Silt	M. exalbescens, P. richardsonii	296.3	1.32	13.2
Stn. 5.	5.5	-	Sand & Clay	V. americana	122.9	0.55	5.5
Transect 2.							
Stn. 1.	1.8	1.8	Silt & Sand	V. americana, M. exalbescens H. dubia, E. canadensis, L. trisulca	471.6	2.1	21.0
Stn. 2.	3.0	3.0	Silt	E. canadensis, C. demersum.	493.6	2.2	22.0
Stn. 3.	5.2	4.3	Silt	No growth	-	-	-
Stn. 4.	1.5	1.5	Silt	M. exalbescens, C. demersum	143.9	0.64	6.4
Transect 3.							
Stn. 1.	3.0	3.0	Silt	V. americana	314.2	1.4	14.0
Stn. 2.	3.0	3.0	Silt	V. americana	-	-	-
Stn. 3.	5.2	4.0	Silt and black muck	No growth	-	-	-

Cont'd....

Table 2 Cont'd.....

Location	Water Depth (m)	Secchi disc (m)	Substrate type	Plant species present	Biomass expressed in grams dry weight per meter square	Equivalent tons per acres dry weight	Estimated fresh weight in tons per acre
Transect 4.							
Stn. 1.	1.5	1.5	Silt	V. americana, A. gramineum H. dubia, L.trisulca	335.8	1.5	15.0
Stn. 2.	1.8	1.8	Silt and black muck	A. gramineum, M. exalbescens	917.6	4.09	40.9
Stn. 3.	4.9	2.5	Clay	V. americana	78.3	0.35	3.5
Transect 5.							
Stn. 1.	1.5	1.5	Silt	V. americana, E. canadensis M. exalbescens	337.3	1.50	15.0
Stn. 2.	2.9	2.9	Silt	M. exalbescens, V. americana, H. dubia	303.6	1.35	13.5
Stn. 3.	4.6	4.3	Clay & Silt	M. exalbescens, V. americana, E. canadensis	201.4	0.90	9.0
Transect 6.							
Stn. 1.	1.5	1.5	Silt & Clay	V. americana, M. exalbescens.	782.2	3.48	34.8
Stn. 2.	4.3	2.6	Silt	M. exalbescens, E. canadensis	1635.2	7.3	73.0

Table 3: Nitrogen and Phosphorus concentrations in plant tissues from the St. Lawrence River

Location	Nitrogen (expressed as a % of the dry weight)	Phosphorus (expressed as a % of the dry weight)
Above Moses-Saunders Dam, near Fraser Island	2.1	0.23
Above Moses-Saunders Dam, near Woodland Islands	1.8	0.20
West of International Bridge and Domtar	2.2	0.24
Approximately 1/2 mile below Cornwall Sewage Treatment Plant, near Pilon Island	3.5	0.39
Near Summertown Marina	2.1	0.25

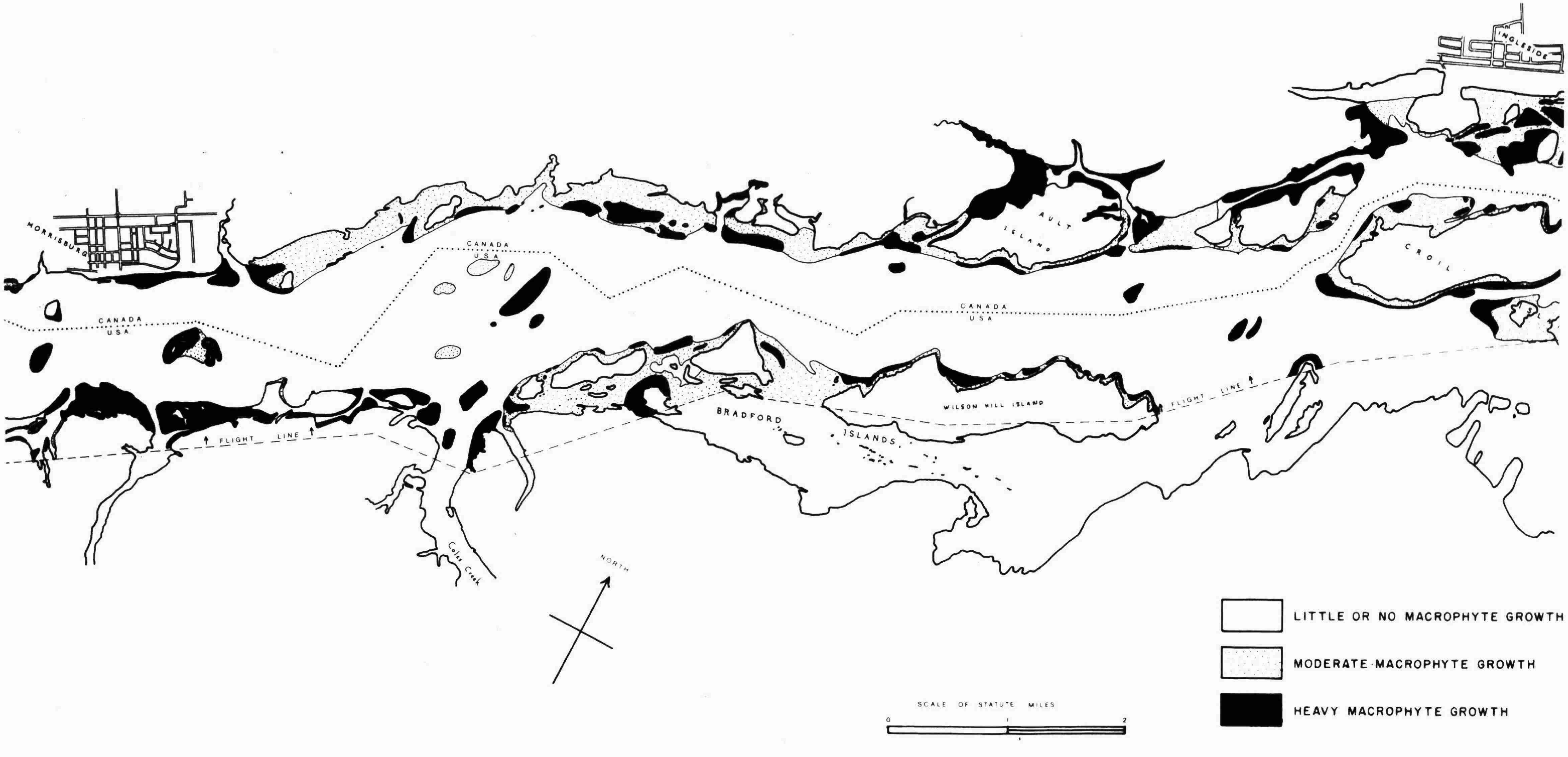

FIG. I. DISTRIBUTION OF AQUATIC VEGETATION IN THE ST. LAWRENCE RIVER

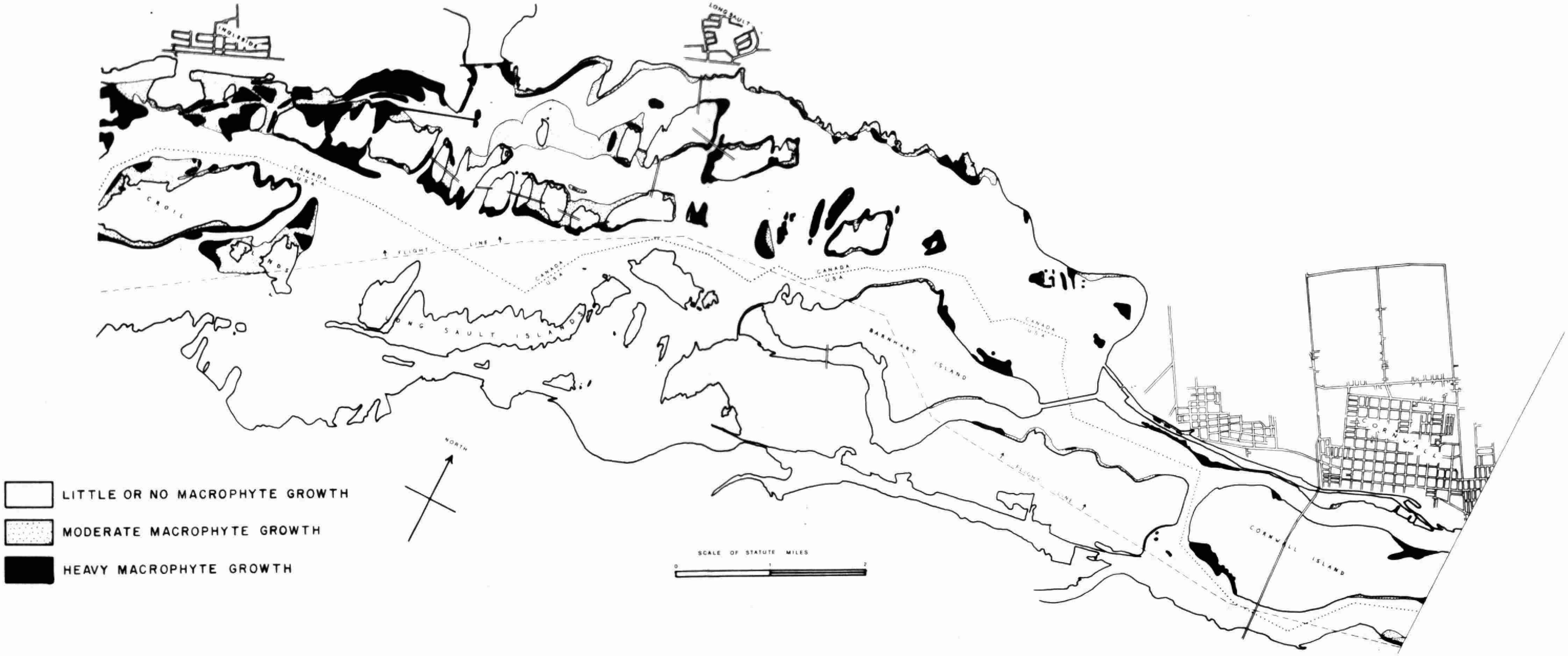

FIG. 2. DISTRIBUTION OF AQUATIC VEGETATION IN THE ST. LAWRENCE RIVER

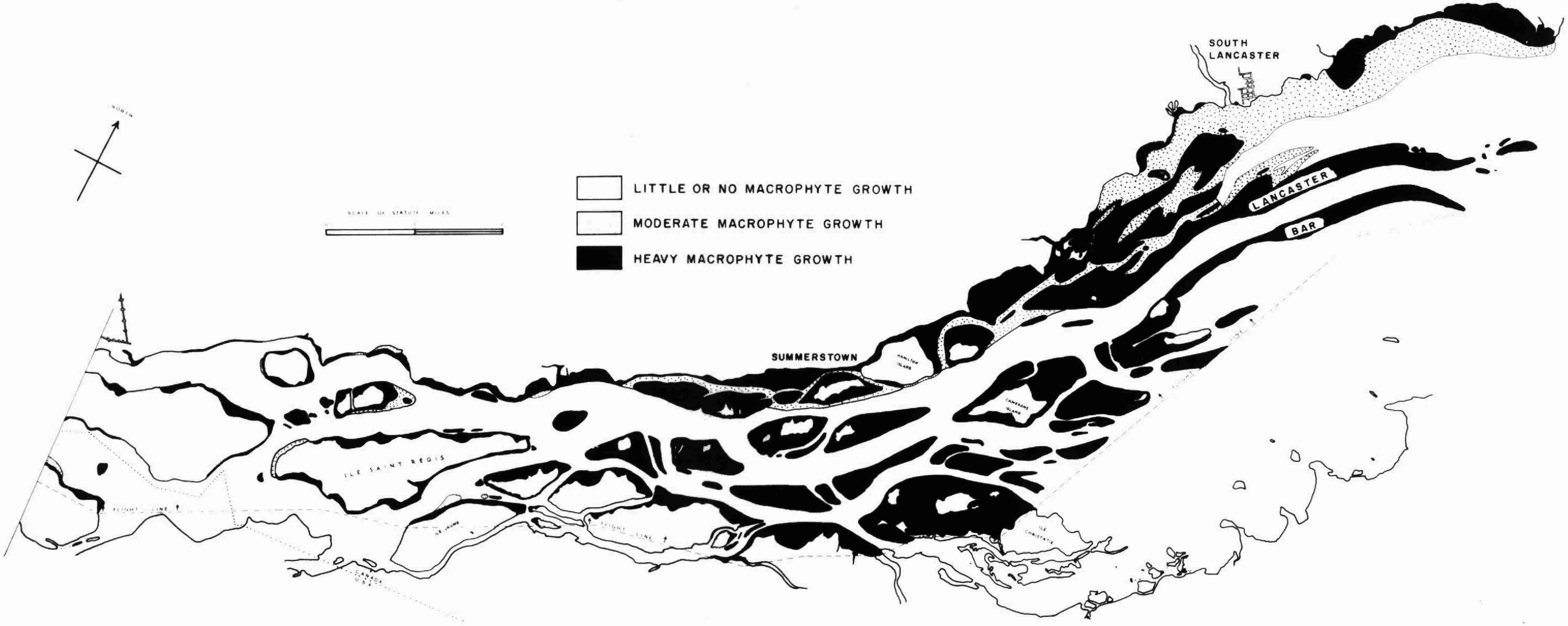

FIG. 3. DISTRIBUTION OF AQUATIC VEGETATION IN THE ST. LAWRENCE RIVER

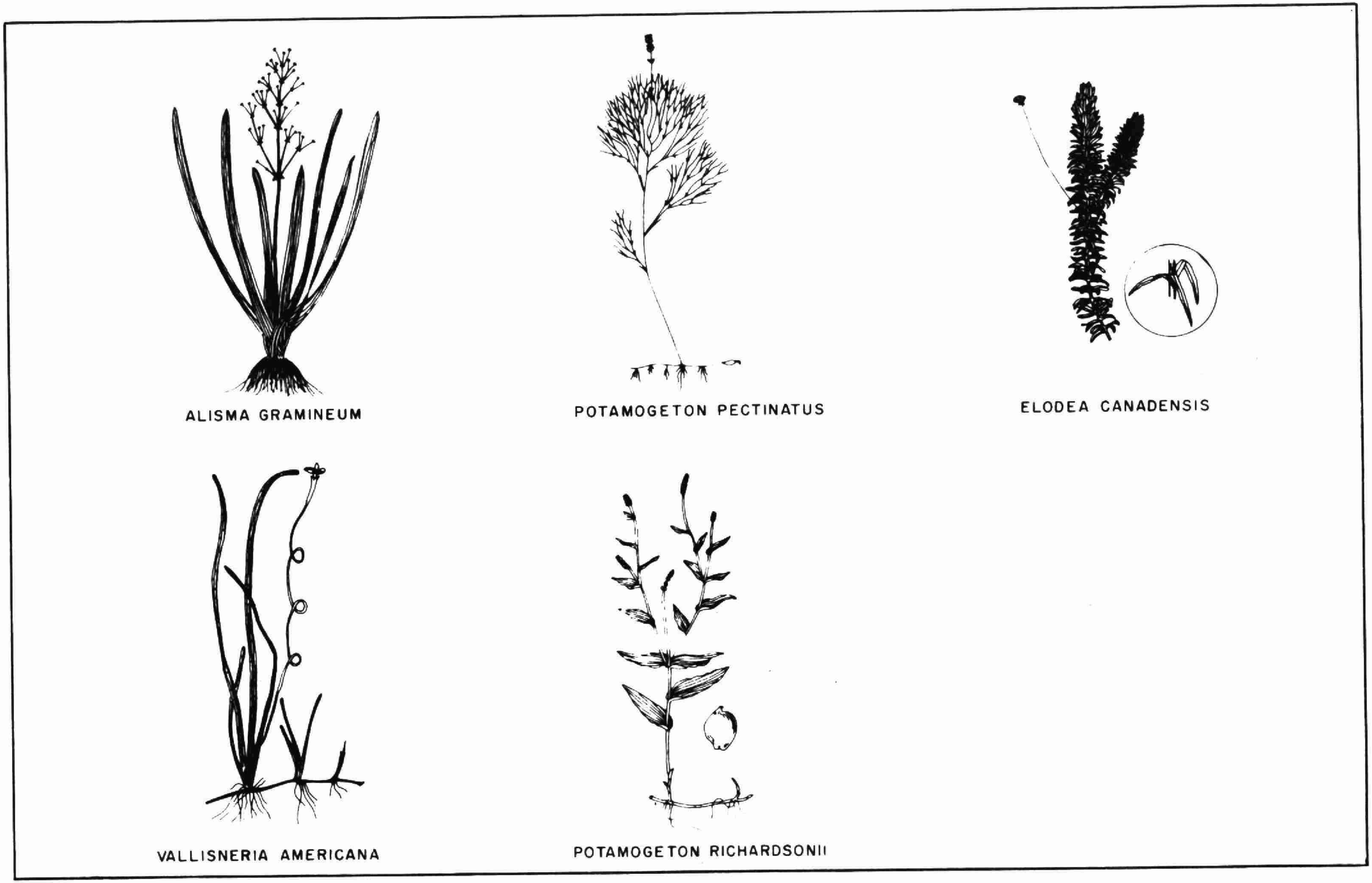

FIG. 4 PLANTS OF THE LAKE ST. FRANCIS AREA OF THE ST. LAWRENCE RIVER

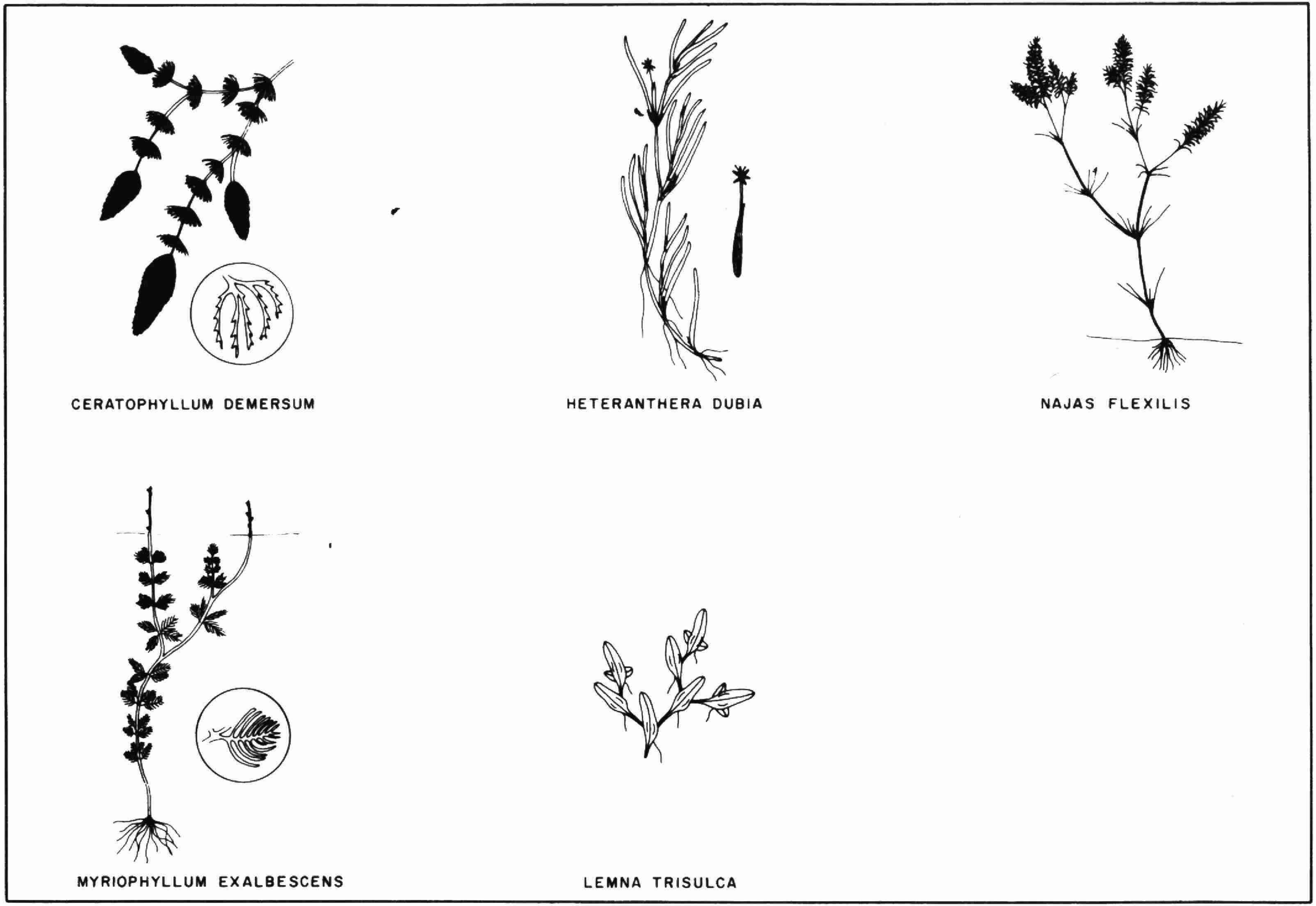

FIG. 5 PLANTS OF THE LAKE ST. FRANCIS AREA OF THE ST. LAWRENCE RIVER

DISCUSSION

Causes

The distribution, variety and abundance of aquatic vegetation generally is determined by a variety of environmental factors and their interactions. Of primary importance are nutrient supply, water depth and clarity, light intensity, water movement and texture of the substrate (usually sedimented materials).

From obervations made in the course of these and earlier studies and the observations of long time residents of the Lake St. Francis area it is clear that the extent and abundance of weed growth have increased substantially since the development of the Seaway.

Although direct evidence of changes in certain physical and chemical characteristics is not available because of the lack of earlier comparative data it is sufficiently clear from available information and our recent observations that major alterations in flow patterns and the composition of sediments over extensive areas of Lake St. Francis have occurred. On the other hand, there is little evidence that would suggest other factors have been significantly altered. For instance water levels which have been controlled at the power dam at Beauharnois, Quebec for approximately the past fifty years have remained relatively constant with monthly mean elevations at Summerstown fluctuating only about one to two feet. Changes in light intensity due to varying meteorological conditions can be expected to cause yearly variations in the abundance of aquatic vegetation but would not account for the sustained trend towards increasing abundance. The high degree of water clarity and therefore light penetration as shown by Secchi disc data presented earlier in this report has reportedly been characteristic of these waters over the long term period. Concentrations of plant nutrients often exert a major influence on the abundance of aquatic vegetation especially under more typical conditions where other environmental factors are relatively stable. Major plant nutrients such as nitrogen and phosphorus, are most often at levels limiting to plant production i.e. they are usually in short supply relative to plant requirements. Nevertheless, from data which are available it would appear that concentrations of nitrogen and phosphorus have not been elevated to the extent which would account for the increased production of weeds in Lake St. Francis. Background concentrations in the eastern basin of Lake Ontario have remained essentially unchanged over the past ten to fifteen years and probably longer. Most point source

inputs to the river, including municipal and industrial waste discharges at Cornwall, have not increased background concentrations appreciably except in areas of initial dilution. Excessive nitrogen loadings to the river from Brockville Chemicals Limited and Dupont (of Canada) Limited and possibly other sources in the Maitland-Ogdensburg area are perhaps a notable exception in view of data published by the International Joint Commission which show an increase in nitrogen concentrations commencing in that portion of the river and persisting downstream to Lake St. Francis. The significance of these and other nutrient loadings from the massive dredging operations and flooding of new lands, which coincided with increased rates of plant production in Lake St. Francis is difficult to assess. However, considering the relatively high concentrations of nitrogen and phosphorus found in plant tissue, which exceeded 1.8% and .20%, respectively, in all samples as compared with concentrations of 1.3% N and .13% P proposed by Gerloff and Kromblatz (1966) as being the critical levels of these elements below which plant growth is limited, it may be that nutrient concentrations have never been a major limiting factor to weed growth nor is it likely that reductions in nutrient loadings will result in limiting concentrations being reached. Measures being implemented to reduce loadings of both nitrogen and phosphorus will have a greater affect in reducing the production of filamentous algae, notably *Spirogyra sp.* which has reportedly increased in abundance in association with the submergent vegetation.

Based on the observations that flow rates have been decreased with a concomitant increase in sedimentation, the dominance of these factors in determining where weeds will grow and the fact that changes in these characteristics have been greatest in the northern and upper portion of the lake where the greatest increase in weed abundance has occurred, it is concluded that the increasing weed problem has stemmed directly from these causes. Furthermore, changes in flow rates must be considered the primary factor involved. As described previously in this report, relatively "stagnant" conditions now exist over extensive areas of the lake where previously strong currents prevailed in several channels and on shoal flats. While several reasons for these changes have been suggested the most logical explanation relates to the ship channel through the Ontario portion of upper Lake St. Francis. This was accomplished by extensive dredging which resulted in the straightening and deepening to a uniform depth of approximately 29 feet of several sections of the original

channel downstream of Cornwall and through the Lancaster Bar. From general observations it is obvious that this channel now carries most of the flow through this section of the lake with significant current velocity being non-existent outside of the ship channel, at least downstream to the Lancaster Bar.

Other possible factors have been suggested. For instance it is commonly believed that construction of the control and power dams, the American locks and creation of the Masena diversion have diverted flows away from the north shore to channels through the southern portion of the lake. This, however, has been refuted by engineers of the St. Lawrence Seaway Authority who confirm that the proportion of the total flow carried by the Cornwall channel and the international channel south of Cornwall Island, which determines the distribution of flow to Lake St. Francis, has been virtually unchanged. If anything, dredging to deepen the ship channel between Cornwall Island and St. Regis Island may have even diverted some of the flow at this juncture to the northern portion of the lake. Also, the view has been expressed that the power and control dams have held back water thereby decreasing flows in Lake St. Francis. The relatively small retention capacity of Lake St. Lawrence, with a turnover period in the order of days, would not be sufficient to allow for major alteration in seasonal or even monthly discharge. Operation of the Moses-Saunders power dam on the basis of peaking power prior to 1971 created considerable within-day variation in discharge to Lake St. Francis. While increased sedimentation during hours of low flow would have been balanced somewhat by increased scouring effects of peak flows, a net positive effect on sedimentation may have resulted. Also, mean annual discharge at Cornwall for the period 1961 to 1967 was considerably lower than the long term average of 240,000 cubic feet per second with a low mean annual discharge of 192,000 cfs in 1965. Although periods of similar low flows have occurred in the past with no apparent effects, it is possible that the low flows of this period and the effects of daily fluctuations both of which coincided with the major channel alterations in Lake St. Francis, have contributed somewhat to the overall problem. It should be noted that relatively minor changes in sediment texture can be significant in the establishment of new weed growth. Once a threshold is reached and weeds become established,sedimentation rates are further increased by an additional reduction in both current velocity and wave-induced agitation

thus serving to expand the weed habitat. One other factor has been suggested as being of some importance. Prior to Seaway development, massive ice floes which developed in and below the international rapids sections of the river moved downstream through Lake St. Francis during the spring break-up. It has been suggested that the scouring action of these floes may have prevented the accumulation of finer sediments in shoal areas although the significance of this can only be speculated on.

Thus while the combined and additive effects of several factors may have contributed to the weed problem in Lake St. Francis, it is believed that the dominant factor has been the change in flow patterns effected by channel alterations.

Potential Solutions

In considering weed control measures emphasis should initially be placed on rectifying the primary causes, which, if feasible, may offer the best solution on a permanent basis and in the long term may be the most economical. However, it is often the case that causative environmental factors are not amenable to change either because of their magnitude or because of technological and/or economic considerations. In Lake St. Francis it is not likely to be feasible to restore the hydrological characteristics of the pre-Seaway era. Before discussing more practical considerations it is worth noting that had adequate attention been given to the completion of a comprehensive assessment of the environmental impact of Seaway development in the planning stages, ecological effects would have been identified and would likely have resulted in a more acceptable alternative design of the navigational channel through Lake St. Francis. At this stage, weed control efforts in Lake St. Francis will have to be restricted to alleviating the weed problem in specific areas of the lake.

The numerous techniques which have been utilized throughout the world to control nuisance growths of aquatic vegetation have been summarized in Appendix I. Although chemical treatments are currently the most widely used methods in Ontario and can be effectively used by cottagers to create small swimming areas, their application to the extensive problems in Lake St. Francis would undoubtedly create undesirable effects, particularly, oxygen depletion and nutrient recycling. On the other hand, mechanical removal of nuisance vegetation is considered to be a more viable alternative in terms of environmental consequences provided the harvested vegetation is

removed from the water to prevent decay and creation of unaesthetic conditions. To fully assess both the ecological and practical implications of large scale mechanical harvesting, an experimental programme was initiated in Chemung Lake in 1973. Although any biological changes which may occur as a result of the harvested operation are expected to be of a subtle nature and not apparent within a limited time span, preliminary data show no significant changes in the populations of the four major game fish species (musky, pickerel, small and large mouth bass) in Chemung Lake. Decreases in the perch population have been noted although the causes of the changes have not been clearly established. Some assessments of small forage fish trapped in the harvested vegetation have also been completed and the data indicate an average of 0.9 kg (or 2 lbs) of fish, mainly perch and pumpkinseed, are removed per ton of harvested vegetation. Studies on the changes in the plant populations are still largely inconclusive; however, increases in plant densities following repeated cutting have not been noted. Regrowth rates of the vegetatation appear to be quite rapid, often necessitating re-cutting within a single season. Considerable effort has also been expended in assessing the potential of the harvested vegetation for use as livestock feed or a soil additive. While many problems remain unresolved, particularly methods of contending with the high moisture content and variable composition of the vegetation, commercial utilization may be a viable future possibility.

In view of the inconclusive nature of current information, the broad application of weed harvesting techniques would not be desirable at the present time. However, because of the extensive weed habitat in Lake St. Francis and the need for control over relatively small areas, it is felt that implementation of a weed harvesting programme would restore much of the lost recreational potential without significant ecological risk. If undertaken, the programme should initially be established on a fairly small scale, utilizing one large harvester unit with back-up transporter barges and shore conveyor systems, to clear selected nearshore areas and boating access to main navigation channels. This operation could be readily expanded in the future as dictated by local requirements and economic considerations.

Based on available information, a single harvesting unit operation in Lake St. Francis could anticipate an average productivity rate of 0.5 to 0.6 acres per hour. Assuming an eight hour working day over a 66 day season, weed control could be achieved over some 270 acres and could for example consist of a 150 ft wide swath parallelling the shore over a distance of some ten miles, twenty access channels 100 ft. x 500 ft. in size and clearance of some

nearshore areas. A programme of this magnitude would also generate over 1000 tons (wet weight) of vegetation which could be hauled to nearby farms to be utilized as an organic soil additive following compositing. As an alternate disposal method, the vegetation could be processed through a forage chopper at a suitable land site and made available to local residents for use as a garden mulch.

Dredging to remove nutrient rich sediments or to alter the textural consistency of substrates, especially in areas where sedimentation and siltation have covered sand or gravel bottoms, is generally considered an effective method for eradicating aquatic vegetation. However, at costs varying between $0.45 and $2.00 per cubic yard, this method is prohibitively expensive on a large scale. While the use of this method to control plant growths extensively throughout Lake St. Francis would not be practical, dredging of secondary channels to restore their full usefulness for recreational boating should be considered. This method would be especially applicable to the area of the north shore between Danis Point and South Lancaster and to areas of extensive flats where access to open water channels towards the south shore is desirable. The design of these channels would be an important consideration since sufficient water flow must be provided to discourage future development of nuisance plant growths.

Over-winter drawdown to expose aquatic vegetation to freezing and desication has been frequently used as a control measure. Beard (1973) found a 70% reduction in the acreage covered by aquatic plants following application of the drawdown method in the Murphy Flowage. Similarly Lantz et al (1964) reported drawdown as 90% effective in removing plants from Anacoco Lake, Louisiana and 50% effective in Lafourche Lake, Louisiana.

Although the utilization of this method in the Lake St. Francis area does present immense difficulties in terms of recreational disruption, interprovincial and international impact and a reduction in power production at the Hydro Quebec Generating Station, the concept may merit further investigation. A partial drop in water level of some 5 feet for a two week to one month period could be effected after closing of the shipping season; however, it would require extensive planning and co-ordination and approval from a wide range of controlling interests.

CONCLUSIONS

To alleviate the problems of restricted water usage and aesthetic deterioration caused by the excessive growth of aquatic vegetation along the north shore of Lake St. Francis, the implementation of the following control measures should be considered:

1) Implementation of a weed harvesting programme to clear nearshore recreational areas and to provide boat access to main navigation channels.

   a) Due to the inconclusive nature of available information on the biological and practical implications of large scale vegetation removal, the Ministry of the Environment does not recommend the implementation of aquatic plant harvesting on a broad scale at the present time. However, due to the extensive areas of weed habitat in Lake St. Francis and the possibility of significantly improving recreational potential by removing weed growths over relatively small portions of the lake a programme could be initiated on a fairly small scale utilizing a single large harvester unit plus necessary back-up equipment.

   b) The harvesting programme could readily be expanded in the future as dictated by local requirements, economic considerations and pending development of additional impact information and policy directives.

   c) Harvesting of aquatic vegetation should initially be concentrated in acute problem areas to create access to open water and to facilitate swimming and boating activities in "nearshore high-use areas". The specific locations to be included should be established in consultation with the Ministry of Natural Resources and the Ministry of the Environment.

2) In conjunction with the weed harvesting programme, dredging of major secondary and additional access channels to create self-perpetuating boating channels would be an effective means of rehabilitating the most severely afflicted areas.

a) This method would be most applicable to the portion of the north shore between Danis Point and South Lancaster and perhaps to other areas of the lake where access across extensive areas of flats would improve pleasure boating.

b) The design of the channels should be carefully planned to ensure an increase in water flow which would preclude the future development of nuisance aquatic vegetation.

c) The Federal Ministry of Transport should be contacted for approval and for assistance in planning or implementing any dredging programme.

3) A study should be undertaken to establish the practical and ecological acceptability of utilizing temporary drawdown to effect an overall reduction in the density of aquatic vegetation through freezing and deseccation. If feasible, the technique should initially be applied on an experimental basis, with detailed studies of the extent of plant reduction achieved and of the impact on the fisheries.

APPENDIX I

ALTERNATIVES FOR WEED CONTROL: A REVIEW

Excessive growths of aquatic plants are common in waters where depth, light penetration, substrate texture and nutrient levels are conducive to rapid growth. Dense weed beds interfere with many recreational activities such as swimming, fishing and boating and act as filters to trap eroded soil particles, thus accelerating the creation of new shallow areas which they rapidly infest. This tremendous proliferation of plant growth is generally a direct result of human activities such as introduction of highly competitive plant species, siltation resulting from poor land management practices, nutrient enrichment and other forms of environmental disruption.

Aquatic plants, however, when present in moderate quantities play an important role in the aquatic ecosystem. They provide food, shelter and attachment for many kinds of aquatic organisms and spawning areas for many species of fish. Through their root systems, these plants effectively stabilize bottom sediments and during the process of photosynthesis they add necessary oxygen to the water. Therefore the goal of any sound management program should not be eradication of the vegetation but rather the restoration of a healthy ecosystem with a well balanced and diverse aquatic flora.

Many forms of aquatic vegetation control are now practiced throughout the world and the techniques used can be grouped into four general categories: biological controls, habitat manipulation, chemical treatments and mechanical methods.

Biological controls include the introduction of herbivorous fish such as the carp, mammals such as the manatee and various insects, invertebrates and waterfowl to control the nuisance vegetation. Other techniques include the introduction of vigorous plant species which can out-compete undesirable native species or the dissemination of pathogens known to cause plant diseases. These techniques are generally considered the most promising for future success since they provide a continuous controlling force for the undesirable vegetation, however, at the present time they are largely experimental and unsuited to the problem situations in temperate

climates. Furthermore, their use must be approached with extreme caution to prevent substitution of one problem with another.

Habitat manipulation covers a wide range of techniques such as shading, dredging, sand blanketing, water level manipulations and nutrient limitation which can be used to alter one or several of the physical or chemical factors critical for plant growth.

Shading entails use of dyes or floating sheets of black plastic to limit light penetration into the water, thereby restricting plant growth. Dredging has been used extensively to remove nutrient rich sediments and to alter the textural consistency of the substrate, particularly where siltation has covered sand or gravel substrates. However, this technique typically costs in the realm of $0.45 to $2.00 per cubic yard of material removed and can become prohibitively expensive on a large-scale. Blanketing is the process of covering the bottom with a 6 to 8 inch layer of sand or gravel and is generally effective for creating small swimming areas, particularly if the blanketing is done over plastic sheeting. Water level manipulation such as over winter drawdown has been used successfully to expose the aquatic plants to freezing and desiccation. Flooding to increase water depth has also been effective for controlling aquatic vegetation especially emergent species such as cattails and bulrushes. Nutrient limitation techniques such as precipitation of nutrients through addition of alum, fly ash or clay, dilution of nutrient-rich waters with nutrient-poor water and aeration to retard the release of nutrients from the sediments are being actively investigated by researchers throughout the world.

Although many of these habitat manipulation techniques have been used with considerable success in many problem areas they are generally either non-applicable or very expensive for large-scale use.

Chemical treatment entails the use of herbicides or algicides to eradicate undesirable plant growths. Dependent on the type of herbicide used and species of plants present, control can usually be achieved for a 4 to 12 week period at costs ranging between $15 and $90 per acre. Although for reasons of cost and expediency chemical treatment is the most widely used method of weed control it does possess several undesirable drawbacks. For example, the rapid decomposition of the vegetation following chemical applications will frequently deplete oxygen levels and cause fish mortalities.

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Also, nutrients released from the decomposing vegetation become available to other forms of plant life and secondary problems such as phytoplankton blooms may develop in the treated areas. Finally, use of these chemical compounds must be strictly regulated to prevent excessive dosages and resultant toxicity to other forms of aquatic life.

Information on recommended herbicides, required dosage rates, methods of treatment, use restrictions and application forms for a permit can be obtained from M.O.E., Pesticide Control Services, 1 St. Clair Ave. W., Toronto.

Mechanical control measures usually consist of cutting of the vegetation and removal of the cuttings with an aquatic harvestor, or later, in a secondary operation. Removal of the cuttings is essential to avoid the nuisances caused by large quantities of drifting, decomposing vegetation. Although, less popular than chemical treatment, mechanical control is generally considered a sounder management alternative since it does not introduce foreign toxicants into the water and by removing only the upper portions of the plants its impact on the life cycles of a lake is undoubtedly less drastic. Moreover, this method removes considerable plant biomass from the system, thus avoiding the problems of oxygen depletions and as an added bonus the nutrients contained in the plant biomass are removed from circulation. However, at the present time, the effects of mechanical cutting on most plant species are not well documented and it is difficult to specify optimum cutting procedures and seasonal timing. Similarly, the effects of large-scale vegetation removal on fish populations, fish food organisms and water quality have not been clearly established.

A wide variety of machinery is commerically available at costs ranging between $1000.00 for small cutters to $35,000.00 for large aquatic harvesters (Table 1). These machines generally have capacities ranging between 0.3 to 1 acre per hour, considerably lower than the rates achieved in similar mechanized agricultural practices. As a result, operational costs are frequently high (Table 2) with various estimates between $15 and $90 reported in the literature. Disposal costs are frequently an added expenditure often necessitating haulage to distant land fill sites.

To make mechanical harvesting more acceptable as a control measure, substantial improvements in harvesting rates, handling and disposal must be achieved. Ideally, if commercial uses could be developed for the harvested vegetation, the economics of the situation could be considerably improved.

CURRENT STATUS OF THE M.O.E. EXPERIMENTAL HARVESTING PROGRAMME

The experimental harvesting programme was iniated in Southern Chemung Lake in 1973 for the purpose of assessing both the ecological and the practical implications of large-scale vegetation removal. Specifically, concurrent with our harvesting efforts, detailed studies are underway to monitor changes in fish populations, fish food organisms and in the plant populations including shifts in specie composition, rates of regrowth and optimum cutting times. On the practical side, we are evaluating the capabilities and limitations of existent machinery and investigating potential methods of recycling the harvested plant material into usable products such as soil additives and livestock feeds.

To date no undesirable biological effects, such as, significant changes in the main game fish species or increases in phytoplankton levels have been noted. However, possible changes in the juvenile age groups of the game fish are difficult to detect and may not be apparent within a limited time span. Similarly, the implications of the removal of considerable numbers of small forage fish (i.e. perch, sunfish, minnows) which are trapped in harvested vegetation have not been fully assessed.

Harvesting operations were commenced in early August in 1973 and in mid-June in 1974, utilizing an Aquamarine Harvester with a variety of transport barges and shoreline conveyor systems. Harvesting rates are generally low ranging between 0.45 and 0.55 acres per hour, thus emphazing the need for additional mechanical modifications to produce a more satisfactory rate. Based on the regrowth of vegetation in the harvested areas, it is apparent that a second cutting is required particularly in areas infested with water milfoil. An average of 3 tons of vegetation was removed per acre and trucked to adjacent farms for disposal. In most cases, the vegetation was composted throughout the summer and applied to the fields with manure spreaders and cultivators in early fall.

In an attempt to find commercial uses for the harvested vegetation, experimental quantities were pelletized at an alfalfa meal plant, ensilaged and composted by an aerobic process. Feeding trials are currently underway at the University of Guelph to establish the usefulness of the silage and pellets as livestock feeds. Similar greenhouse trials

with the composted plants are in progress. Following completion of these experiments the economics of processing the plant material into livestock feeds or soil additives must be investigated to ensure a viable operation. Naturally, the unresolved problems encountered to date are extensive. Specifically, the high water content of the plants, usually in the realm of 90% by weight poses a major problem in terms of energy requirements for drying prior to processing, transportation and spoilage during transit.

APPENDIX 1

TABLE 2: Harvesting Budget Calculation Sheet provided by Aquamarine Corporation using their equipment.*

I.	Capital Investment for Equipment:		
	Harvester	$ 36,800.00	
	Shore Conveyor	8,500.00	
	Mobilizing Assembly	2,490.00	
	Freight	1,200.00	
		$ 48,990.00	
	Annual Depreciation $38,593 ÷ 10 years		$ 4,899.00
II.	Leased Truck and Hauling Expense: 200 miles per day; 5-day week; 66-day season.		
	Leasing Fee - $290 x 3 months	$ 870.00	
	Mileage Cost - 200 miles x 66 days @ 10¢	1,320.00	
	Gasoline - (200 miles x 66 days x 10¢) ÷ 10 mile/gal.	264.00	
			$ 2,450.00
III.	Labor:		
	8-hour day; 66 days; 2 men @ $4/hour/man (includes fringe benefits)		
	8 hours x 66 days x 2 men x $4/hour		$ 4,224.00
IV.	Harvesting Operating & Maintenance Expense		$ 1,500.00
V.	Contingencies (10%)		$ 1,300.00
	ANNUAL ESTIMATED OPERATING COST		$ 14,377.00

		ACRE/SEASON	COST/ACRE
at 1 acre/hour x 8 hours x 66 days	=	528 acre/season	$27.25
at 1/2 acre/hour x 8 hours x 66 days	=	264 acre/season	$54.50
at 1/3 acre/hour x 8 hours x 66 days	=	176 acre/season	$81.70

* Gasoline and labour costs have not been adapted to Canadian conditions.

APPENDIX 1

TABLE 1: Manufacturers of Weed Harvesting Equipment

Company	Address	Model	Cutting Bar Capacity	Cutting Speed	Removal Method
Air-Lec Industries	3300 Commercial Ave. Madison, Wisconsin	-	W = 3½ft. (105 cm) D = 3½ft. (105 cm) boat mounted.	3-6 mph (4.8 - 9.6 kph).	8ft./(240cm) rake available for raking to shore
American Water-weed Harvesting Company	14901 Minnetonka Industrial Road, Minnetonka, Minn.	Harvester	W = 16ft. (480 cm) D = 6ft. (180 cm)	3 mph (4.8 kph) 10 mph (16 kph) Transport speed	Cutter unit loads on to attached 50 ft. (15m) self-unloading barge.
		Shore Line Cleaner	W = 7ft. (210 cm) D = 4ft. (120 cm)	3-6 mph (4.8 - 9.6 kph)	10 ft./(300 cm) rake available for raking to shore
Aquamarine	1116 Adams Street Waukesha, Wis.	650	W = 8ft. (240 cm) D = 5 ft. (150 cm)	1½ mph (2.4 kph)	Aqua-trio combination includes self-unloading harvester, transport barge and shore conveyor
		Sawfish	W = 8ft. (240 cm) D = 5 ft (150 cm)	1½-2 mph (2.4 - 3.2 kph)	L-shaped front end loading rake.
Hockney Company	913 Cogswell Dr. Silver Lake, Wis.	HC-10	W = 10ft. (300 cm) D = 5ft. (150 cm)	4 mph (6.4 kph)	Rake attachment for raking to shore.
		HC-7 Boat Mounted	W = 7ft. (210 cm) D = 4ft. (120 cm)	4 mph (6.4 kph)	Rake attachment for raking to shore

W = Width of cut
D = Maximum depth of cut

(Current prices can best be obtained by writing directly to the manufacturers).

APPENDIX II

WAYS AND MEANS TO FUND AQUATIC WEED CONTROL EQUIPMENT

"This article is a condensation of a paper given at the July 15, 1974 meeting of the Hyacinth Control Society by one of their directors C. Brate Bryant, President of Aquamarine Corp., Waukesha, Wisconsin."

Lake property owners have a very special problem. They pay a premium for their property so that they can enjoy their beautiful lakes and they find that the quality of their lakes are going down as the weeds come up. They know that they have to spend some money to solve the problem and it isn't even too hard to come up with the conclusion that weed harvesting is the best way to solve the problem. But, the real stickler is how to afford the solution. Obviously, contracting for weed harvesting services is a practical answer. However, the number of harvesting contractors in the business is small as compared with the number and size of the problem areas. For the broad spectrum of weed problem areas then I think we can realistically cancel that option out from a list of ways to accomplish weed harvesting. As time goes by however, this condition will change and harvesting contractors will rise up to meet the need. If we accept this as fact, then the problem boils down to that of acquiring equipment and arranging for its operation. It is the purpose of this paper to analyze a number of alternative ways of financing the acquisition of weed harvesting equipment.

A good example of creative thinking which leads to one solution is described in this Aqua-Views lead article on Oakland County, Michigan. There the Public Works Committee of Oakland County committed the necessary monies to acquire equipment. The County's Drain Commission was entrusted with the operation of - and invoicing for - the weed harvesting equipment's services in various lakes. In essence, then, here was the temporary use of tax monies to get over the initial hurdle of a large lump sum payment. The harvester is now profitably paying itself off over a period of time and weeds are being harvested where they never would have been harvested if it had been left only to the resources of the lake property owners.

A second, but similar, story is that of Lake Nagawicka in Delafield, Wisconsin. Their lake property owners association made things happen in this case. Coincidently one of their association members was a City of Delafield Alderman. Weed harvesting equipment was purchased using

Delafield's money. The operational costs of the unit were handled by the lake property association who collected contributions. This latter operational arrangement was soon phased out when it became apparent that contributions could not realistically be counted on for continuing periods of time. The operation of the harvesting equipment then reverted back to the City of Delafield's budget.

A third device for funding harvesting is usually available under state law. Usually these laws (which do vary) allow any given area to legally poll the tax payers or citizens of that area on the setting up of a special legal entity variously called Sanitary or Watershed Districts. These districts then have the right, by majority vote usually, to assess themselves taxes for certain purposes among which are water quality efforts, refuse pickup and the like. Taxes usually are levied on an assessed evaluation basis or sometimes on a shoreline basis. But in any case, this approach is a most direct way to work in harmony with the apparent fact that weed harvesting must involve some tax dollars at some level if the program is going to be a successful, on-going maintenance effort. A good example of a successful Wisconsin effort in this area is the East Troy Sanitary District No.1 made up of riparian owners on Lake Beulah. Their success has been well documented and the figures on the whole story are available through Aquamarine Corporation reprints. A similar effort was mounted at Kelowna, British Columbia, Canada where the Okanagan Basin Water Board has acquired and is operating a harvesting system.

A little bit different approach is that of Dane County, Wisconsin. The City of Madison, Wisconsin, has a number of large weedy lakes which extend beyond the city limits. Dane County had taken responsibility for the lake areas outside of the City of Madison and the lakes found themselves with two major weed harvesting operations going on at the same time. When the City Council in Madison voted unanimously to cancel all further herbicidal weed control expenditures, it became evident that a consolidation of the two weed harvesting programs into one more efficient large program was the only way to go. Dane County now handles the program exclusively with tax dollars flowing into the program from the City of Madison. Their budget on weed harvesting is annually over $100,000. It might be well to mention here than Dane County is chopping their harvested weed and distributing this chopped material to five pick-up points. The demand for the chopped weed by Madison's tax paying gardeners is heavy enough that a bid to take over all the output of the

harvesting operation had to be turned down. The time when this end product can be sold and contribute toward the cost of the harvest is not far away in Dane County.

The State of California Department of Water Resources bought a harvester and leases it out to other California state agencies. The department involved with the purchase of the unit uses a similar method of operating on other large equipment purchases. There are advantages to this approach in that the department which makes the purchase has a great deal of expertise in financing, write-offs, leases and maintenance which allows the leasing department to stay clear of all these financial and bookkeeping details.

A sixth method of accomplishing the acquisition of capital for weed harvesting has been proposed as follows:

> A partnership of people with financial resources (called in Wisconsin "limited partnerships") can be set up to purchase the necessary equipment. Then, a lease back arrangement with a lake property association or another entity, such as a sanitary district or city, can be arranged. Under certain circumstances, this can be financially attractive for the partners in the limited partnership, taxwise, through the use of accelerated depreciation allowances. The higher the tax bracket is in which the partners find themselves, the more tax advantage realized by the partners. Depending upon the leasing figures which the partnership charges, savings can be passed back to the operators of the harvester. Notice that the partnership members do not have to get involved in the operation of the unit in any way. They are only a vehicle to accomplish acquisition of harvesting equipment and can be largely insulated from any risk.

Lastly, leasing of equipment from a leasing company should always be looked at closely. It is usually used as a last resort for the lease fees usually exceed that of any other proposal depending, of course, on what your alternatives are. Usually a leasing company wants to know who they are dealing with and, depending upon the stability of that group, the cost of money will rise or fall. The leasing company seldom has an interest in taking over the equipment in the event of a default in payments so the arrangement is usually what is called a "lease purchase arrangement" where the unit is leased for an agreed upon number of years and at the end of that period, the title for the harvester reverts to the leasee. Sometimes a leasor will

request from the maufacturer of the weed harvester what is called partial or total "recourse". The manufacturer has to agree to this facet of the contract and then becomes part of that contract. He in effect says "I will take back the equipment in the event of default by the leasee under the following terms:" Then the terms are worked out to everyones satisfaction.

There are more examples but basically they all have a common denominator: tax monies seem to get involved in each of the methods. In recognition of this apparent fact, matching dollars through specially funded State or Federal programs seem to be finding their way down to the problem. For instance, the Florida Department of Natural Resources has a sizeable matching fund program. Wisconsin is working on a landmark law which would help fund lake refurbishment projects. There is a clean water bill passed in Washington, D.C. (public law 92-500 - amending the Federal Water Pollution Control Act) which may result in some significant funds being committed to this area through state programs. The law "authorized to be appropriated" $300,000,000 through 1975. Even local efforts can raise considerable funds. For instance certain counties in Florida add a special fee to their fishing licenses with the funds being tabbed for water quality. On Nagawicka Lake, there is a Waukesha County Park boat launching site. Each boat owner pays a launching fee, some of which finds its way to the weed harvesting program on Nagawicka. Generally, where there is a will there is a way. For the same reason that roads get plowed when there is a snowstorm, lakes that get fertilized will be harvested. As usual, it will be imagination and determination that will get the job done.

APPENDIX III

Utilization of aquatic plants by fish and wildlife.

Plants	Value as food	Remarks
Potamogeton (pondweeds) P. pectinatus P. richardsonii	Excellent	Due to their wide distribution, pondweeds form the staple diet for waterfowl. Most waterfowl consume the entire plants, although many species show a preference for certain parts (i.e. nutlets, roots, winter buds). Pondweeds are also heavily eaten by muskrats, beaver, deer, moose and various marsh and shore birds and provide food and shelter for fish. P. pectinatus is the most important specie of pondweed, particularly relished by ducks for its nutlets and tubers. P. richardsonii is of lesser importance in waterfowl diets.
Najas (bushy pondweed) N. flexilis	Good	The stems, foliage and seeds of bushy pondweed are important sources of food for waterfowl and provide food and cover for fish. N. flexilis is especially preferred by Mallards
Elodea (waterweed) E. canadensis	Fair	Elodea is of variable importance to waterfowl. Small quantities of the plants have been found in the stomachs of mallards, blue-winged teal and goldeneye. It is sparingly eaten by muskrats and beaver. It shelters small aquatic life, an important source of fish-food and provides shelter for fish.
Valisneria (wild celery, tapegrass) V. americana	Excellent	Excellent food source for ducks. All parts are eaten although the propagating buds and root stocks are relished most. The propagating buds are largely consumed by the diving ducks. The non-diving ducks, get occasional buds but largely feed on the foliage. Tapegrass also provides good shade and shelter and a valuable food source for fish.
Ceratophyllum (coontail) C. demersum.	Good	Seeds are consumed by practically all species of ducks. The foliage is eaten less frequently. Coontail is also an important food source for muskrats, supports many forms of aquatic insects which are valuable as fresh-food and provides good shelter for young fish.

Cont'd....

Plants	Value as food	Remarks
Myriophyllum (water milfoil) M. exalbescens	Fair	Most waterfowl eat the fruits of these plants but only a few species consume the foliage. Water milfoil is sparingly eaten by muskrat and moose but is a valuable food producer for fish. Roots of M. exalbescens are preferred by black bass for nesting.
Heteranthera (mud plantain) H. dubia		Is locally attractive to some species of waterfowl (pintail, blue-winged teal and wood duck). Provides food and shelter for fish.
Lemna (duckweed) L. trisulca	Good	An important food source for most waterfowl, pheasants, beaver and muskrat. It is a poor food producer for fish.
Alisma (water plantain) A. gramineum	Poor	Nutlets eaten by some waterfowl. A generally unimportant food source.

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